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VARIATIONS IN UROSALPINX

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1. *Introduction*.—In a paper which appeared in 1898 Bumpus¹ showed that, in the case of *Littorina littorea*, an introduced species shows more variability than the same species in its original habitat. This *Littorina* was recently so rare on the Atlantic coast that two pioneer specimens were reported by Verrill from Woods Hole in 1875 while the first specimen found at New Haven was in 1880. Twenty years later it was probably the commonest mollusk to be found along the new England coast and its range extended northward and southward considerably beyond this area. Three lots of 1,000 each, representing the former habitat of the species, were obtained from the coasts of Wales, Scotland and England, respectively, and these shells were measured so as to get an index of their variability. Then ten 1,000-lots of the introduced American shells were collected and measured for comparison and it was found that nowhere in any of the ten different localities, which extended from the St. Croix River in Maine to Newport, R. I., could shells be found that did not have a greater index of variability than did the British shells. Duncker² working over

¹ Bumpus, H. C., 1898, "The Variations and Mutations of the Introduced *Littorina*," *Zool. Bul.*, Vol. I, pp. 247-259.

² Duncker, G., 1898, "Bemerkung zu dem Aufsatz von H. C. Bumpus: The Variations and Mutations of the Introduced *Littorina*," *Biol. Centralbl.*, Bd. 18, pp. 569-573.

Bumpus's data afterwards by the most approved technical methods, confirmed his conclusion.

The oyster-borer, *Urosalpinx cinereus* Say, offers an additional opportunity to test the relative variability of a species when introduced into a new environment as compared with the same species living in the original habitat. This mollusk is a native of the Atlantic coast, living particularly on the oyster beds, where it causes considerable damage. In 1871 Mr. A. Booth, of Chicago, first transplanted the Atlantic oysters to the Pacific coast where, with varying success, they have since been maintained. Two lots of these shells were obtained from the San Francisco beds in 1898 and it was the original purpose of this paper to compare these introduced California shells with individuals from the Atlantic coast whence they were emigrated.

The work was principally done at the Woods Hole research laboratory of the U. S. Fisheries Bureau and I wish hereby to acknowledge the many courtesies received from the officers connected with that bureau, and particularly to express my indebtedness to Professor Bumpus who suggested the original problem. I wish also here to thank the following persons for aid in obtaining specimens: Dr. Bumpus for 1,500 California shells; Dr. H. M. Smith for 1,700 from Prince's Bay, Staten Island; Mr. G. W. Hunter, for 1,000 from Norwalk Harbor, Ct.; Miss M. E. Smallwood for 1,000 from Cold Spring Harbor, Long Island; Mr. C. T. Brues and Mr. A. L. Melander for 8,000 from Woods Hole, Mass., in 1902 and 1903; and Mr. C. S. Bennett for 4,000 from Woods Hole in 1908. Finally, I am particularly under obligation to Dr. J. Arthur Harris, who very kindly passed the manuscript under his statistical eye. It should be added that while Dr. Harris is responsible for much that does not appear he is in no way committed to what remains.

2. *Methods*.—In collecting, only living specimens were taken, thus eliminating beach-worn shells, and collecting was always done "systematically at random" (Daven-

port) so that any lot would, as far as possible, be typically representative of its locality. Lots of 1,000 were taken and shells not immediately measured were simply preserved in formalin until opportunity for making use of them arose.

In ascertaining statistically the variability of any lot of shells it was necessary to select for measurement two easily definable dimensions common to every shell and take the ratio of these two dimensions for reasons which will directly appear. The dimensions selected were the total height of the shell (a to b , Fig. 1) and the greatest dimension of the shell-aperture (a to c , Fig. 1). It was possible to determine these standards on *Urosalpinx* by the use of calipers with a considerable degree of accuracy. Any other dimensions which would lend themselves equally well to accurate measurement would have served quite as well to establish a criterion from which a comparison of variability in different lots of shells could be computed, since it was the *fact* of variation, and not the direction or character of it that was the object of the inquiry.

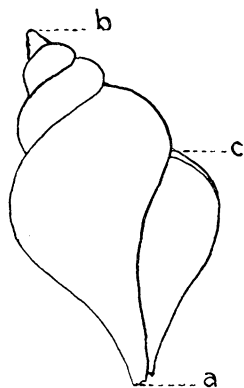


FIG. 1. $a-b$ = height of shell, $a-c$ = greatest mouth aperture.

The ratio of the two dimensions was used instead of a single dimension in order to eliminate as far as possible heterogeneity referable directly to growth. Had height alone, for instance, been used then groups of shells would be related to each other with reference to their variations in size or age only, and all that could be said in comparing lots from two localities would be that those in one locality averaged taller or shorter, and presumably, therefore, were older or younger than those from another locality. This would not be a suitable index for variation in form. On the other hand, when the ratio of two dimensions is taken, then the factor of absolute

size is eliminated, while the factor of form remains. Thus a shell 20 mm. high with a greatest shell-aperture of 12 mm. would fall in the 60 per cent. class ($20:12=60$ per cent.), as would also a smaller shell 15 mm. high with a greatest shell aperture of 9 mm. ($15:9=60$ per cent.), while shells of the same height as the first, but with a 14 mm. greatest shell aperture, would rightly represent a variation in form since they fall into a different (70 per cent.) class ($20:14=70$ per cent.). This distinction may be more apparent by reference to Fig. 2 where

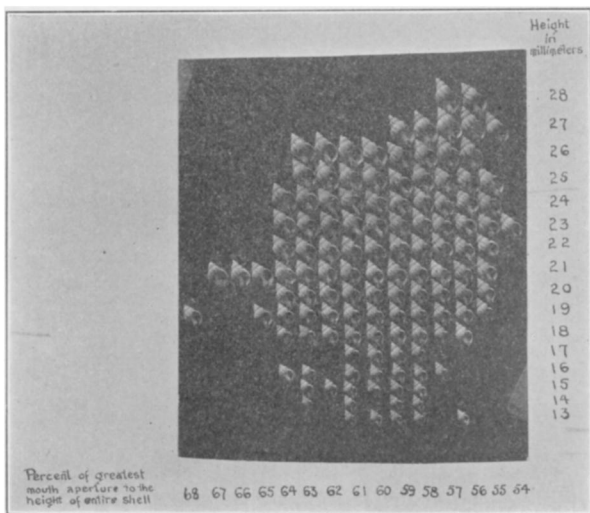


FIG. 2. The different classes of variants occurring in a specimen lot of one thousand shells to show how size, or the factor of growth, was eliminated in classifying the variants. The shells in the vertical lines all in the *same* percentage class, although their size (height) differs. The shells in the horizontal lines are in *different* percentage classes, although their size (height) is alike.

single representatives of all the different classes of variants that appeared in a certain thousand-lot of shells are arranged to show this point. Here the shells in any horizontal row are the same height, and have, therefore, presumably reached the same stage of growth, but at the same time they are all unlike in form since those at the left have larger "greatest shell apertures" than those at the right. On the contrary, all the shells in any vertical

row, although varying in size, fall into a single form-group as determined by the ratio between total height and the greatest shell-aperture. A measuring machine such as that used by Bumpus for his work on *Littorina* made it possible to read the ratio of the two dimensions directly from a graduated arm without trouble of computation, thus greatly lessening the tediousness in obtaining the data.

3. *Are Variation Curves of any Locality Distinctive for that Locality?*—Tests were first made to ascertain how far the personal element in making the measurements could affect the results, since judgment in the use of calipers and in the manipulation of the measuring machine are by no means invariable factors. One such test, which is typical of several which were made, is shown in Table I, where the same lot of shells was twice measured.

TABLE I

THE SAME LOT OF A THOUSAND SHELLS TWICE MEASURED TO SHOW AMOUNT OF ERROR IN MANIPULATION.

Percentage Class.	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	Arithmetical Mean.	Standard ³ Deviation.	Probable ³ Error.
First measuring	1	2	2	5	28	58	118	185	182	171	139	49	38	15	5	2	62.101	1.992	$\pm .0300$
Second measuring		2	2	4	25	66	128	182	179	176	120	59	33	18	4	2	62.071	2.088	$\pm .0314$
Difference																	.030	.096	

The numbers ought to be identical. Their deviation from exact similarity represents the imperfections of manipulation and it will be seen that according to this test a difference of .096 in the standard deviation with a probable error of about $\pm .03$ may be regarded due to imperfect technique.

Now in order to test whether the variation is characteristic and constant for any locality whence the shells came, two 1,000-lots were gathered on the same day in 1898 from the same restricted group of rocks on Nobska Point, Woods Hole, by no means thereby exhausting the

supply. The figures for these two lots are shown together in Table II.

TABLE II

TWO LOTS OF SHELLS OF ONE THOUSAND EACH TAKEN FROM THE SAME ROCKS AT THE SAME TIME TO SHOW THE PROBABLE VALIDITY OF PLACE-MODES.

Percentage Class.	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	A. M.	σ	P. E.
First lot		2	3	20	40	80	150	149	196	157	112	57	21	10	4	1	61.737	2.152	.0323
Second lot	2	2	31	14	61	79	144	148	185	160	106	55	25	10	7		61.694	2.234	.0336
Difference																	.043	.082	

The close resemblance of these two lots, which show a difference in standard deviation (.082) less than that shown when the same lot is measured twice (.096) as just indicated in Table I, warranted confidence in the probability that all the shells from a given place, when collected at the same time, exhibit the same characteristic sort of variation which may therefore be regarded as distinctive for that particular locality. Furthermore, a glance at Table III will show how widely the shells of various localities may differ with regard to the character and degree of their variability, a fact that assures us that in *Urosalpinx* we are dealing with a form whose variation is considerable enough to furnish favorable material for quantitative treatment.

* Formulas for standard deviation and probable error of standard deviation are found in Davenport's Statistical Methods (Davenport, C. B., 1899), as follows:

$$\text{Sum of } \sqrt{\frac{\text{Standard deviation} = \sum[(\text{deviation of class from mean})^2 \times \text{frequency of class}]}{\text{Number of variates}}} \quad \text{or}$$

$$\frac{\sum \sqrt{(x^2 \cdot f)}}{n}$$

$$\text{Probable error of standard deviation} = \frac{\text{Standard deviation}}{\pm 0.6745 \sqrt{2 \times \text{number of variates}}} \quad \text{or P. E.} = \pm 0.6745 \frac{\sigma}{\sqrt{2n}}$$

TABLE III

TWO LOTS OF SHELLS OF ONE THOUSAND EACH TO SHOW EXTREMES OF VARIATION.

Percentage Class.	50	51	52	53	54	55	56	57	58	59	60	61	62	63
Devil's Foot	1	0 ⁺	2	6	22	38	99	144	193	217	163	73	25	14
Prince's Bay						4	5	9	36	45	65	79	132	84
Percentage Class.	64	65	66	67	68	69	70	71	72	73	A. M.	σ	P. E.	
Devil's Foot	3										58.358	1.849	.0279	
Prince's Bay	83	117	75	88	83	42	33	15	2	1	63.976	3.407	.0514	
Difference											5.618	1.558		

4. *A Comparison of Atlantic with Pacific Shells.*—In the summer of 1898, following the method employed by Bumpus with *Littorina*, 7,006 *Urosalpinx* shells from various localities near Woods Hole were obtained and measured, with which were compared 1,528 introduced shells from two localities in California. From Table IV, in which these data are brought together, it will be seen that Bumpus's work on *Littorina* is apparently confirmed, that is, there is more variability in the introduced than in the endemic form, although the margin of probable error permits an overlapping in some instances.

TABLE IV

ATLANTIC AND PACIFIC SHELLS COMPARED.

Locality.		Number of Shells.	A. M.	σ	P. E.
Woods Hole	West Shore	1,001	58.928	2.339	$\pm .0352$
	Penzance Point	1,002	61.718	2.737	$\pm .0412$
	Nobska Point	1,002	61.737	2.152	$\pm .0324$
	Nobska Point	1,001	61.944	2.234	$\pm .0337$
	Nobska Point	496	66.944	2.366	$\pm .0507$
	Barnacle Beach	998	63.932	2.604	$\pm .0393$
	Big Wepecket	1,006	57.426	2.052	$\pm .0308$
	Mid Wepecket	500	57.606	2.098	$\pm .0447$
Average			61.066	2.335	$\pm .0386$
California	Belmont Beds	1,008	59.051	3.023	$\pm .0454$
	San Francisco Bay	220	60.892	3.361	$\pm .0703$
Average			59.664	3.138	$\pm .0538$
Difference				.803	

5. *Shells from Buzzard's Bay and Vineyard Sound Compared.*—For the sake of scientific peace of mind the

incident should have been closed at this point, but uncertainty as to the degree in which the element of time took part in influencing the place-modes of variability led to the examination during the following summer of several thousand more shells. Four convenient localities near Woods Hole (see Fig. 3) where *Urosalpinx* was abundant were selected and three lots of 1,000 each were collected from each of these localities at intervals of two weeks apart. The data obtained from these shells is arranged in Table V.

TABLE V

WOODS HOLE SHELLS ARRANGED TO SHOW PLACE VARIATION AFTER TWO WEEKS INTERVALS OF TIME.

Locality.		Time when Collected.	Number of Shells.	A. M.	σ	P. E.
Buzzard's Bay	West Shore	July 5	1,000	58.669	2.137	$\pm .0322$
		July 21	1,000	59.598	2.211	$\pm .0333$
		Aug. 5	920	60.308	2.211	$\pm .0323$
	Average		59.503			
	Penzance Point	July 5	986	58.458	2.137	$\pm .0304$
July 21		1,000	58.030	2.135	$\pm .0322$	
Aug. 5		1,000	60.308	1.982	$\pm .0323$	
Average		58.888				
Vineyard Sound	Nobska Point	July 5	1,000	62.085	2.040	$\pm .0307$
		July 21	1,000	62.690	2.172	$\pm .0327$
		Aug. 5	1,005	64.022	2.312	$\pm .0347$
	Average		62.934			
	Barnacle Beach	July 5	1,036	60.978	2.093	$\pm .0310$
July 21		1,001	61.925	2.119	$\pm .0319$	
Aug. 5		1,001	63.281	2.186	$\pm .0329$	
Average		62.048				

From Table V it will be seen that in each of the four localities the arithmetical mean (A.M.) increased steadily, except for the Penzance Point—July 21—lot of shells. This general increase may be due to the fact that, as the season advanced, there were fewer young shells in any 1,000 lot. The young are produced in May and June from individuals that have wintered over, so that early in July the *Urosalpinx* community is made up of old adults from the preceding year and of young of various sizes. A month later the population is more uniform,

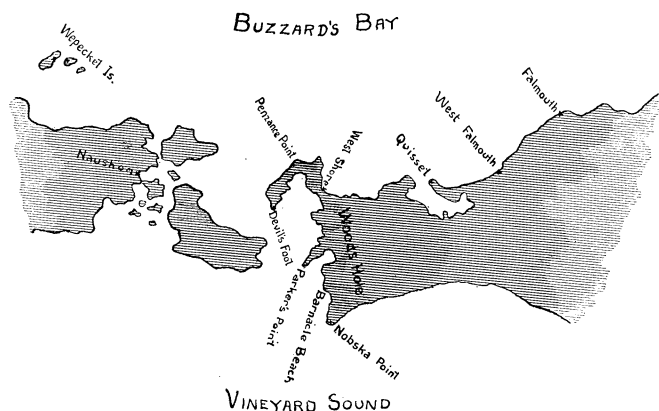


FIG. 3.

due to the rapid growth and approaching maturity of the young ones. That the ratio of the two dimensions used changes somewhat with age is shown in a later table (Table VII), a fact that somewhat complicates a comparison between shells of any two localities. It will furthermore be observed that the variability of the Vineyard Sound shells as indicated by their standard deviation increases steadily from July 5 to August 5, reaching its maximum upon the latter date, but that for both the Buzzard's Bay localities the same is not true; on the contrary, in the case of Penzance Point the August 5 collections showed the *least* variability of any time. The fact that the maximum of the shifting seasonal variation does not occur at the same time in localities almost within sight of each other, as in the present instance, plainly indicates that comparisons of variabilities based upon the time-factor alone do not take everything into consideration. The shells from Buzzard's Bay range in their arithmetical mean from 58.030 to 60.308 while those from Vineyard Sound, separated from the former only by the narrow tongue of land on which the village of Woods Hole is located, form a distinct class ranging from 60.978 to 64.022. Here is a distinct place difference in the shells of the two general localities in question.

Shells obtained from other localities in Buzzard's Bay

and Vineyard Sound conform quite closely with respect to their arithmetical means to the standards above mentioned.

6. *Time and Place Factors Compared.*—When a comparison of the standard deviation of these 1899 shells is made to ascertain whether the greater variability is associated with time (due to inherent germinal modifications), or with place (associated with environmental modifications), it appears that while time is rather the more important factor, yet the result is not uniform and convincing. This comparison is shown in Table VI, in which the difference between the standard deviation of the July shells of each locality with the July 5 shells of three other localities is obtained to indicate differences due to place, and second, the difference between standard deviation of the July 5 shells in each locality and those of July 21 and August 5 for the corresponding locality are reckoned to show the effect of time.

TABLE VI

A COMPARISON OF THE DIFFERENCES IN THE STANDARD DEVIATION VARIABILITY OF THE 1899 WOODS HOLE SHELLS ARRANGED ACCORDING TO THE PLACE-FACTOR AND THE TIME-FACTOR.

Place Differences (July 5).				Time Differences.		
Nobska Point.	West Shore.	Penzance Point.	Barnacle Beach.	July 5.	July 21.	August 5.
—	.097	.025	.053	Nobska Point	.132	.272
.097	—	.122	.044	West Shore	.074	.080
.025	.122	—	.078	Penzance Point	.120	.033
.053	.044	.078	—	Penzance Beach	.026	.093
.058	.088	.075	.058	Average	.088	.119

In Table VI, if we first consider the case of the Nobska Point shells in the top line of the table and utilize those collected upon July 5 as a standard for comparison it appears that shells from the same locality but collected two and four weeks later show a greater difference in variability (standard deviation) than shells collected from any of the three other neighboring localities upon the same date of July 5. That is, the factors dependent upon time

play a greater part in determining the amount of variability than do the factors dependent upon place. Furthermore, there is a greater difference of variability after four weeks (.272) than after two weeks (.132) have elapsed, just as would be expected if a progressive time change is taking place. The same general result appears also when an average of the four localities is reckoned, as shown in the bottom line of the table, but an examination of the second, third and fourth lines of the table reveals several instances in detail of non-conformity to this apparently general conclusion that time has more to do with determining variability than place. It is apparently safe to conclude, however, that the factors dependent upon time are at least as important, if not demonstrably more so, than those dependent upon space or locality.

TABLE VII

WOODS HOLE SHELLS ARRANGED ACCORDING TO THEIR SIZE.

Height in mm.	Actual No. of Shells.	A. M. Per Cent.	σ	P. E.
11	96	64.070	3.487	$\pm .1753$
12	139	63.911	3.558	$\pm .1445$
13	252	63.372	3.465	$\pm .1049$
14	341	62.983	3.954	$\pm .1029$
15	524	62.940	3.602	$\pm .0755$
16	866	61.960	3.020	$\pm .0489$
17	1,296	61.595	3.146	$\pm .0417$
18	2,033	61.171	3.124	$\pm .0325$
19	2,328	60.913	3.143	$\pm .0311$
20	3,366	61.004	3.209	$\pm .0227$
21	4,404	60.914	3.056	$\pm .0219$
22	4,807	60.739	3.122	$\pm .0213$
23	3,836	60.507	2.881	$\pm .0222$
24	2,854	60.171	2.951	$\pm .0276$
25	1,782	59.856	2.943	$\pm .0322$
26	949	59.706	2.663	$\pm .0412$
27	539	59.520	2.704	$\pm .0555$
28	239	59.213	2.520	$\pm .0777$
29	109	59.654	2.907	$\pm .1328$
30	63	59.305	2.740	$\pm .1646$
31	30	58.334	2.182	$\pm .2455$
32	23	58.665	1.916	$\pm .1905$
33	6	58.332	4.015	$\pm .7818$
34	12	59.083	3.009	$\pm .4141$
35	5	57.600	2.059	$\pm .4392$
36	3	60.000	8.185	± 2.2554
37	1	54.000		
Total	30,903			

7. *Variations due to Age.*—It is indeed true that as the snail grows older not only is there a change in the total height of the shell, as would be expected, but also the ratio of the largest shell-aperture to the height diminishes in a definite way and the standard deviation becomes generally less. In other words, the older the shell becomes the less is the relative size of the largest shell-aperture to the total height and the less does it tend to deviate from the arithmetical mean. In Table VII the total number of shells measured in 1898, 1899, 1900 are arranged according to their height to illustrate this fact.

8. *Staten Island and California Shells Compared.*—In 1900 shells were obtained from several additional localities, among which were 1,665 from oyster beds on Prince's Bay, Staten Island. This lot of shells has a special interest because it was from this particular locality, according to Dr. H. M. Smith, of the U. S. Fish Commission, that the oysters, and accidentally with them the *Urosalpinx*, were obtained for transplanting to San Francisco in 1871. A comparison of the Staten Island shells with the California shells appears in Table VIII.

TABLE VIII

A COMPARISON OF CALIFORNIA SHELLS WITH THOSE FROM STATEN ISLAND.

	No.	A. M.	σ	P. E.
California	1,528	59.741	3.286	$\pm .0398$
Staten Island	1,664	63.166	3.508	$\pm .0412$

From this table one of three conclusions must be drawn: (1) That the introduced California shells vary less in their new environment than they did in the place they came from or (2) that the Staten Island shells have increased remarkably in their variability since 1871, or (3) that place-modes in which time element is not known are of little value in working with organisms of this kind.

9. *Shells of Successive Years Compared.*—Further-

more, the analysis of the 1899 shells indicates that a proper comparison of place-modes of variability could be made only on material of the same relative age, which presumably could be approximated best by collecting the shells in neighboring localities at the same time or in any one locality at the same time in successive years. Consequently lots of 1,000 shells from each of the four Woods Hole localities mentioned in Table V were collected during the first week of August, with some omissions, for several years. These data are assembled in Tables IX and X.

In Table IX it is made apparent that, when the time element is reduced to a minimum by comparing only August 5 shells of various years, the shells of Buzzard's Bay (West Shore and Penzance Point) fall into a group distinct from those of Vineyard Sound (Nobska Point and Barnacle Beach), at least so far as the A. M. is concerned. The A. M. of 11,476 Buzzard's Bay—August 5 shells is 61.330 while the A. M. for 14,503 Vineyard Sound—August 5 shells, is 64.303. In no individual lot of Buzzard's Bay shells does the A. M. reach as high as the Vineyard Sound average and in no one lot of the Vineyard Sound shells does the A. M. fall as low as the Buzzard's Bay average of 61.330.

The standard deviation of the August shells shows no decided grouping with reference to Buzzard's Bay and Vineyard Sound, although those from the latter locality show a slightly higher total average which is probably quite without significance. In general, then, it may be said that during the first week of August the Buzzard's Bay shells show a lower ratio of greatest shell-aperture to height (and consequently may be regarded as rather more advanced in their life cycle) than those of Vineyard Sound, but that they present no significant difference in variability.

In each of the two general localities which were more exposed to the open water and the beat of the waves, viz., Nobska Point and Penzance Point, is the variabil-

TABLE IX

A COMPARISON OF AUGUST SHELLS OF VARIOUS YEARS TO SHOW
PLACE-VARIATION.

Place.		Time.	Number.	A. M.	σ	P. E.	
Buzzard's Bay	West Shore	1898	1,001	58.928	2.339	$\pm .0352$	
		1899	920	60.308	2.057	$\pm .0323$	
		1900	405	60.711	2.042	$\pm .0484$	
		1901	—	—	—	—	
		1902	1,000	63.251	3.280	$\pm .0491$	
		1903	1,000	61.419	2.234	$\pm .0336$	
		1904	—	—	—	—	
		1905	1,000	61.086	2.012	$\pm .0303$	
		1906	—	—	—	—	
		1907	—	—	—	—	
		1908	1,000	60.380	2.469	$\pm .0372$	
	Total		6,326	60.890	2.663	$\pm .0160$	
		Penzance Point	1898	1,002	61.718	2.737	$\pm .0412$
			1899	1,000	60.170	1.982	$\pm .0299$
			1900	1,001	60.617	2.008	$\pm .0316$
			1901	—	—	—	—
			1902	1,000	64.155	2.938	$\pm .0443$
			1903	1,000	62.773	2.086	$\pm .0314$
			1904	—	—	—	—
			1905	1,000	61.381	1.970	$\pm .0775$
			1906	—	—	—	—
			1907	—	Too scarce to collect	—	—
			1908	—	—	—	—
Total		5,150 11.476	61.870 61.330	2.814 2.805	$\pm .0187$ $\pm .0125$		
	Vineyard Sound	Nobska Point	1898	2,498	62.751	3.041	$\pm .0290$
1899			1,005	64.022	2.312	$\pm .0347$	
1900			1,000	66.396	2.449	$\pm .0369$	
1901			—	—	—	—	
1902			1,000	66.775	2.707	$\pm .0407$	
1903			1,000	64.605	2.128	$\pm .0321$	
1904			—	—	—	—	
1905			1,000	63.765	2.653	$\pm .0400$	
1906			—	—	—	—	
1907			—	—	—	—	
1908			1,000	63.296	2.719	$\pm .0410$	
Total			8,503	64.205	3.048	$\pm .0158$	
		Barnacle Beach	1898	998	63.942	2.604	$\pm .0393$
	1899		1,000	63.281	2.186	$\pm .0329$	
	1900		1,000	66.798	2.052	$\pm .0309$	
	1901		—	—	—	—	
	1902		1,002	66.085	2.351	$\pm .0354$	
	1903		1,000	63.526	2.546	$\pm .0383$	
	1904		—	—	—	—	
	1905		—	Too scarce to collect	—	—	
	1906		—	—	—	—	
	1907		—	—	—	—	
	1908		1,000	63.017	2.300	$\pm .0347$	
Total			6,000 14,503	64.442 64.303	2.602 2.865	$\pm .0160$ $\pm .0113$	

ity (standard deviation) greater than at West Shore and Barnacle Beach, respectively, which were somewhat more sheltered situations.

Turning to Table X, where the August shells are grouped by years rather than by localities, the A. M. is seen to fluctuate with considerable regularity, reaching in 1902 the highest average ratio. It seems not improb-

TABLE X
AUGUST SHELLS GROUPED TO SHOW YEARLY VARIATION.

Year.	Locality.	No.	A. M.	σ	P. E.
1898	West Shore	1,001	58.928	2.339	$\pm.0352$
	Penzance Point	1,002	61.718	2.737	$\pm.0412$
	Nobska Point	2,498	62.751	3.041	$\pm.0290$
	Barnacle Beach	998	63.942	2.604	$\pm.0393$
	Average	(5,499)	61.899	3.389	$\pm.0218$
1899	West Shore	920	60.308	2.057	$\pm.0323$
	Penzance Point	1,000	61.170	1.982	$\pm.0299$
	Nobska Point	1,005	64.022	2.312	$\pm.0347$
	Barnacle Beach	1,000	63.281	2.186	$\pm.0329$
	Average	(3,925)	61.981	2.649	$\pm.0202$
1900	West Shore	405	60.711	2.042	$\pm.0484$
	Penzance Point	1,001	60.617	2.098	$\pm.0316$
	Nobska Point	1,000	66.396	2.449	$\pm.0369$
	Barnacle Beach	1,000	66.798	2.052	$\pm.0309$
	Average	(3,406)	64.139	3.459	$\pm.0281$
1902	West Shore	1,000	63.251	3.280	$\pm.0491$
	Penzance Point	1,000	64.155	2.938	$\pm.0443$
	Nobska Point	1,000	66.775	2.707	$\pm.0407$
	Barnacle Beach	1,002	66.085	2.351	$\pm.0354$
	Average	(4,002)	65.067	3.012	$\pm.0227$
1903	West Shore	1,000	61.419	2.234	$\pm.0336$
	Penzance Point	1,000	62.773	2.084	$\pm.0314$
	Nobska Point	1,000	64.615	2.128	$\pm.0321$
	Barnacle Beach	1,000	63.526	2.546	$\pm.0383$
	Average	(4,000)	63.083	2.542	$\pm.0291$
1905	West Shore	1,000	61.086	2.012	$\pm.0303$
	Penzance Point	149	61.381	1.970	$\pm.0775$
	Nobska Point	1,000	63.765	2.653	$\pm.0400$
	Barnacle Beach	—	—	—	—
	Average	(2,147)	62.077	2.718	$\pm.0280$
1908	West Shore	1,000	60.380	2.469	$\pm.0372$
	Penzance Point	—	—	—	—
	Nobska Point	1,000	63.296	2.719	$\pm.0410$
	Barnacle Beach	1,000	63.017	2.300	$\pm.0347$
	Average	(3,000)	62.321	2.802	$\pm.0244$

able that the missing year 1901 would have furnished a higher maximum than 1902, and that in some future year the high average of 1902 may again be attained.

10. *Dense and Sparse Population Compared.*—Two lots of shells collected in 1899 deserve a separate paragraph. They represent the extremes among all the lots collected with respect to the density of the population. They came from localities on the eastern shore of Buzzard's Bay about five miles apart and were collected during the same week.

TABLE XI

	No.	A. M.	σ	P. E.
Quisset-to-West-Shore	862	60.464	3.127	$\pm .0507$
West Falmouth	1,000	59.091	1.913	$\pm .0297$

The Quisset-to-West-Shore lot was gathered over an area extending fully a mile along the rocky shore and they were so scarce that it was necessary to utilize the low-tide period of two successive days in order to obtain them, and even then only 862 were obtained instead of the usual 1,000. The West Falmouth lot, on the contrary, were all taken within a few minutes from a single rock about five feet in diameter without by any means exhausting the supply.

It may be that the latter, as would be inferred by their proximity, were more closely related to each other than were the former, and consequently they might be expected to present less variation, or it is possible that the Quisset-to-West Shore lot—representing the pioneers or survivors in an apparently inhospitable area—succeeded in maintaining themselves because of their greater variability (*i. e.*, adaptability). Certain it is, at any rate, that they represent the greatest variability (standard deviation) of any lot of shells obtained from the Atlantic coast except a thousand from West Shore in August, 1902, and those already mentioned from Staten Island.

11. *Variation of the Species Urosalpinx as a Whole.*—By combining the data of all the shells measured—a

total of 50,424—it is possible to approximate a measure of the variability of *Urosalpinx* as a species much more nearly than is possible with smaller lots of 1,000. Such a combination is shown in Table XII, which will be seen to furnish the figures for a curve of considerable regularity in which the arithmetical mean is 61.662 and the standard deviation is $3.367 \pm .0071$. This standard deviation is exceeded in but a single instance among the smaller lots which make it up—namely, in the 1,664 shells from Staten Island which show a standard deviation of $3.508 \pm .0412$.

TABLE XII

Per Cent.	50	51	52	53	54	55	56	57	58
No.	4	15	32	120	289	675	1,510	2,450	3,812
Per Cent.	59	60	61	62	63	64	65	66	67
No.	5,052	5,491	5,861	5,515	5,115	4,225	3,647	2,357	1,714
Per Cent.	68	69	70	71	72	73	74	75	76
No.	1,161	737	373	181	54	21	8	4	1

A. M., 61.662. σ , 3.367. P. E., $\pm .007$. Total No., 50,424.

12. *Summary*.—1. When two lots of 1,000 *Urosalpinx* shells each are taken from the same locality they resemble each other sufficiently to indicate a character typical for the locality.

2. Lots of shells from different localities vary widely enough from each other to be easily distinguished, indicating thereby that the varying environment associated with different localities exerts a measurable effect.

3. Endemic Atlantic shells (with one exception noted below) vary less than shells introduced into a new environment (California).

4. The shells of Buzzard's Bay have a lower ratio of greater shell-aperture to shell-height than those of Vineyard Sound.

5. When shells from the same localities in successive fortnights are compared there is an increase in the ratio of greater shell-aperture to shell-height (A. M.) and also a slight increase in variability as shown by the standard deviation, except in the case of the shells from Penzance Point.

6. When growth which we detect by taking into consideration the *time*-factor is compared with the environmental factors that depend upon *place*, the former apparently plays the greater rôle in causing variations.

7. As *Urosalpinx* grows larger (older) the ratio of its greatest shell-aperture to its height diminishes with regularity and its standard deviation tends to become somewhat less.

8. Shells from Staten Island whence the introduced California shells were originally derived show greater variability than the California shells.

9. When the August shells of successive years from the same localities are compared the A. M. of the ratio between the greater shell-aperture and shell-height fluctuates with noticeable regularity, reaching a maximum in 1902.

10. Shells from the localities more exposed to the beat of the waves show greater variability than those from the more protected places.

11. When dense and sparse populations are compared the dense population shows less variability.

12. The average mean of the ratio of greater shell-aperture to height of shell for 50,424 *Urosalpinx* shells is 61.662. The standard deviation is $3.367 \pm .0071$.

13. *Conclusion*.—So far as the statistical method is able to reveal, it is extremely doubtful whether or not *Urosalpinx* when introduced into a new habitat exhibits greater variability than when in its native habitat. The change in the variability appearing in successive fortnights in shells from the same locality as well as in change showing itself in the August shells from the same locality in successive years is marked enough to indicate plainly the working of an ontogenetic variability independent of environmental modification, that is, a *time*-factor as distinguished from a *place*-factor. In consequence of this it is practically impossible to collect homologous lots of individuals of these shells upon which the place- (or environmental-) factor may be accurately determined.